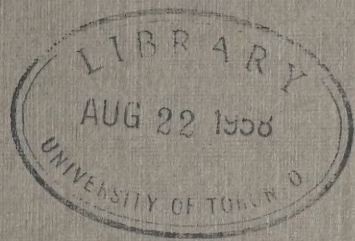


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HYDRO-ELECTRIC INQUIRY COMMISSION

GENERAL REPORT

THE QUEENSTON-CHIPPAWA POWER DEVELOPMENT

✓ WATER  
AVAILABLE  
USAGE  
COST

- VOLUME I—HISTORY AND DESCRIPTION
- ✓ VOLUME II—COST, CAPACITY AND OPERATION
- VOLUME III—ESTIMATES AND APPROPRIATIONS
- VOLUME IV—REASONS FOR INCREASED COST

SEE P 133 - 141

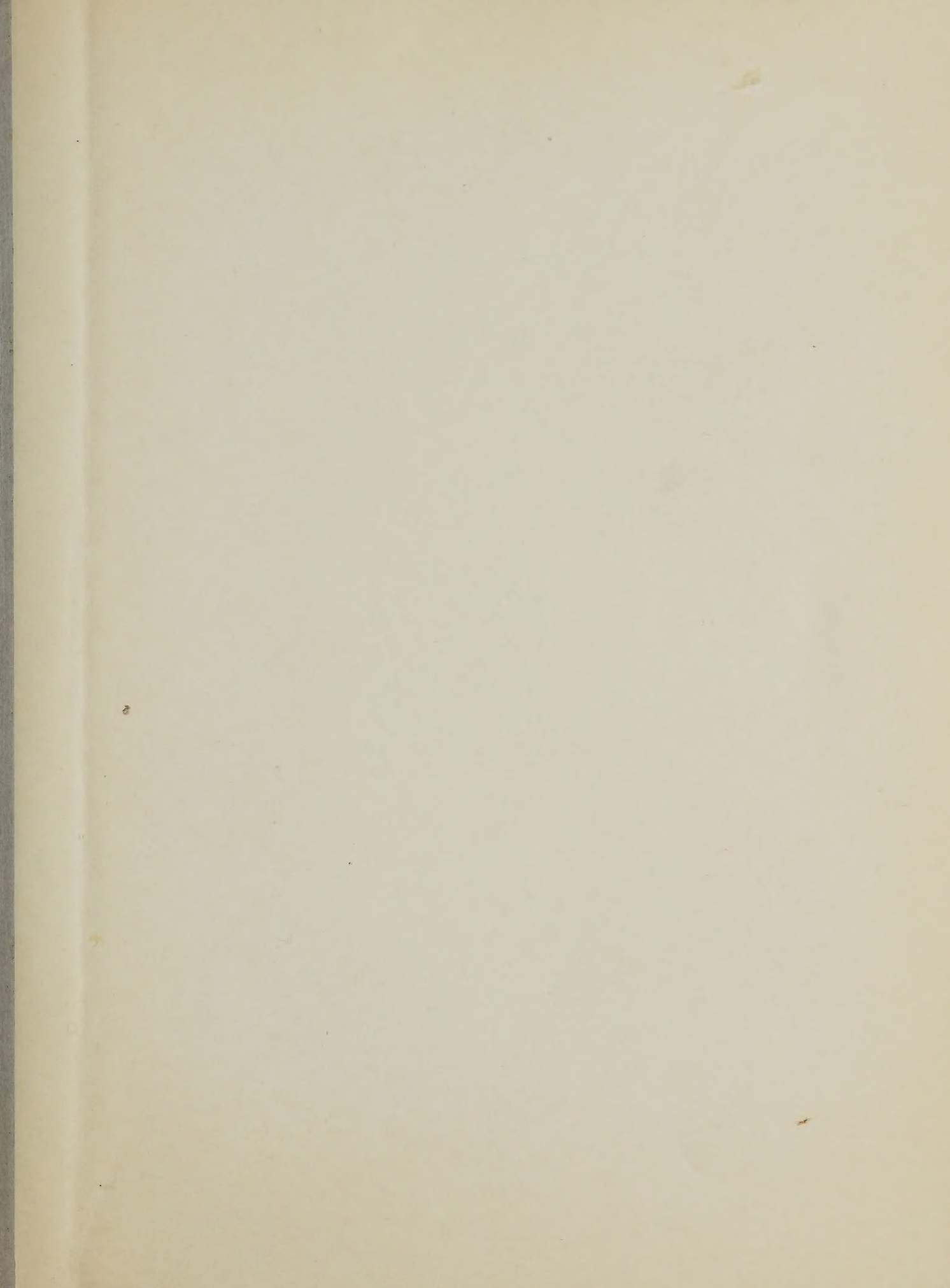
VOLUME II

JOSEPH H. W. BOWER  
SECRETARY
















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## REPORT TO PARLIAMENT'S HOUSE

1971-72

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1971-72

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THE QUEBEC-CHATELAIN POWER DEVELOPMENT

COPY

VOLUME II



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IN REPLY TO MEMORANDUM OF 1907

ON

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## HYDRO-ELECTRIC INQUIRY COMMISSION

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## THE GUNSTON-CHIPPANA POWER DEVELOPMENT

## VOLUME II

## COST, CAPACITY AND OPERATION

PART V - QUANTITIES AND COSTSSection 23SUMMARY OF QUANTITIES

Our Consulting Engineer has discussed quantities and costs in detail in Chapter **COPY** of his report.

We include as pages 121, 122 and 123 charts showing the cubic yards of earth and rock excavated in the various elements of the work and the amount of concrete placed, classified under group headings.

Dealing only with earth and rock excavation it will be noted that the canal constituted by far the most important element in the work. Out of the total earth excavation of 13,500,000 yards, almost 11,000,000 yards came from the canal. Similarly in the matter of rock excavation out of a total of 4,750,000 yards, 3,750,000 yards came from this section of the work.

The quantities of concrete in the canal section bear a similar relationship to the total amount of concrete placed in the whole undertaking. Out of a total of about 370,000 cubic yards, over 300,000 cubic

Hydro-Electric Inquiry Commission  
Distribution of Funds Division  
DISTRIBUTION CHART  
OF EARTH EXCAVATION  
IN CANAL AND FOREBAY



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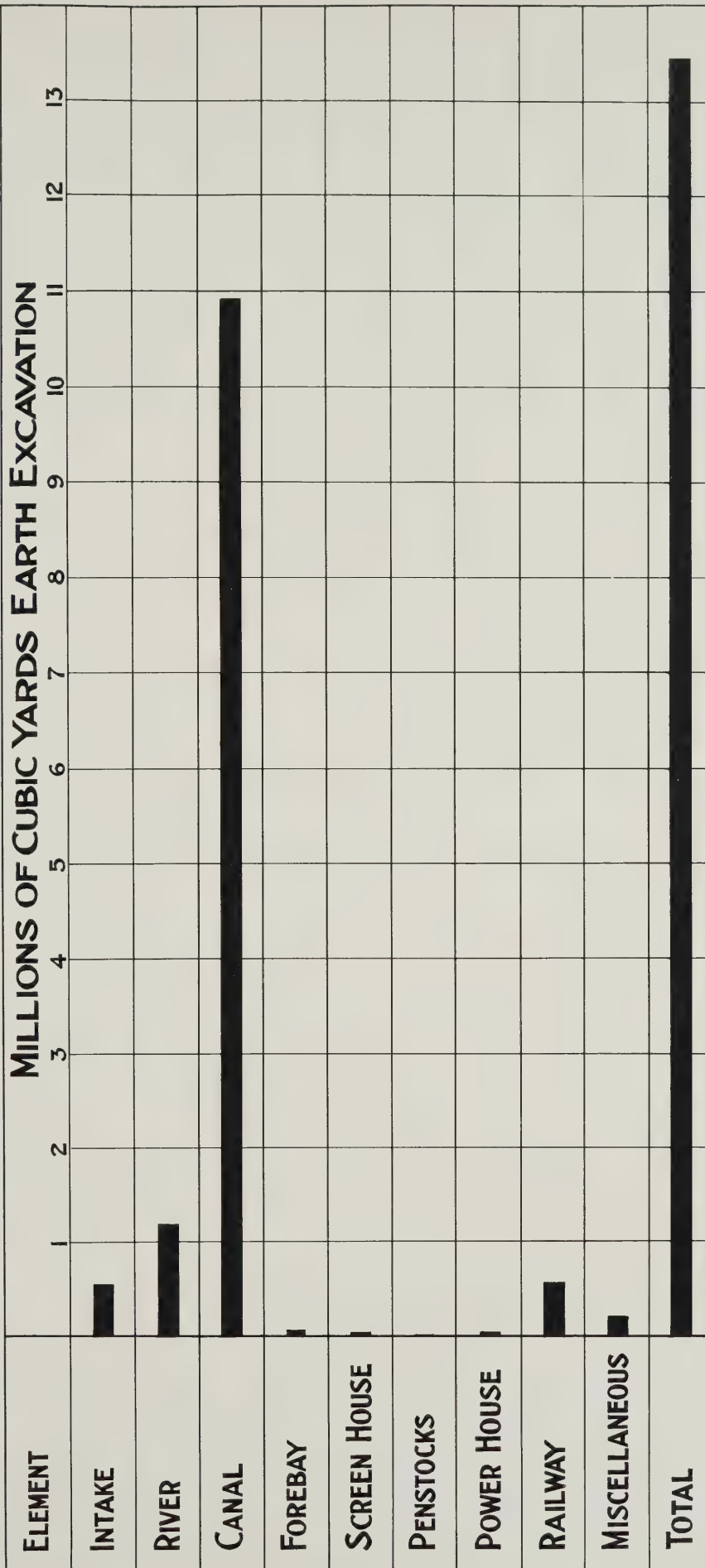
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W.D. GREGORY, CHAIRMAN

**QUEENSTON-CHIPPAWA POWER DEVELOPMENT**

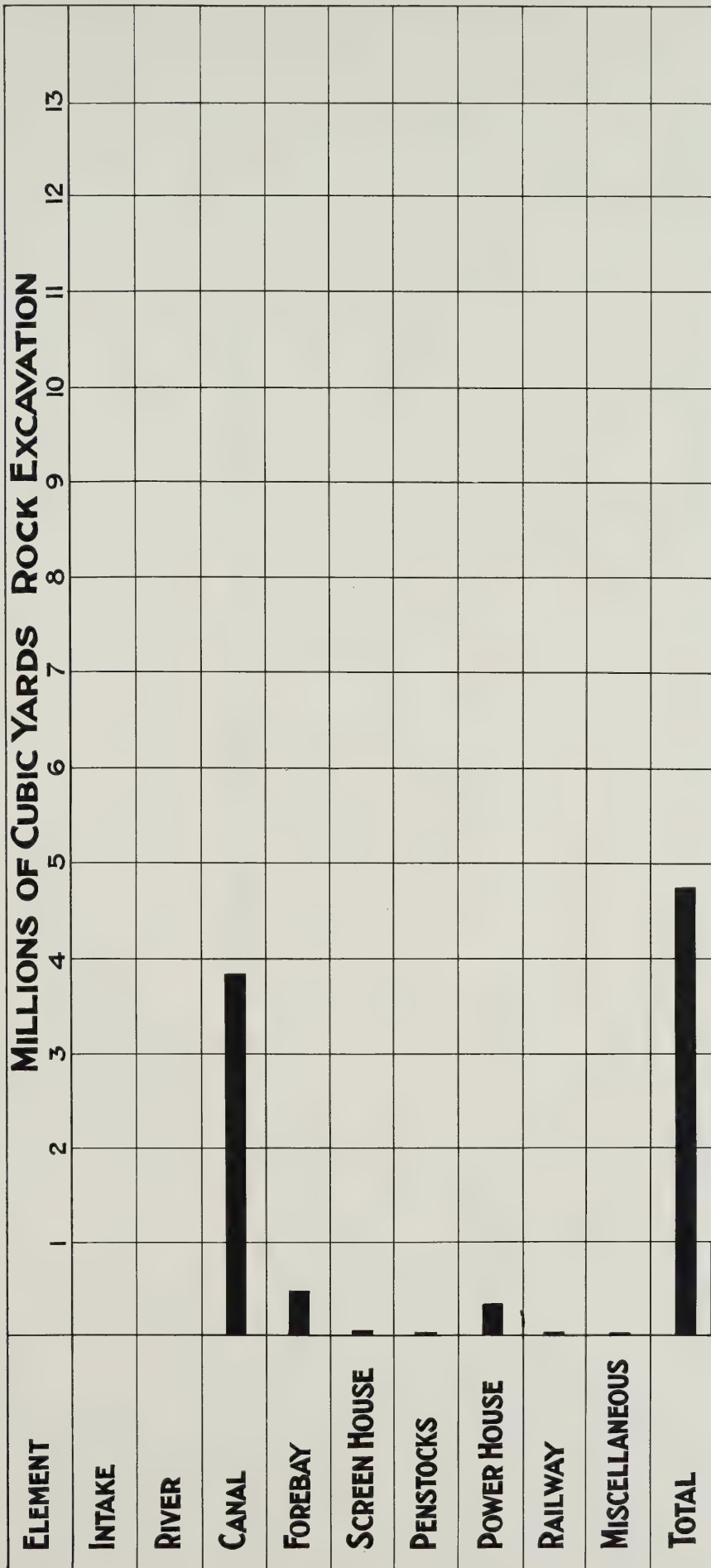
**DISTRIBUTION CHART  
OF EARTH EXCAVATION  
IN CANAL AND FOREBAY**

Toronto, May 3rd, 1923. Made by *G&B* Checked by *WJF*

**WALTER J. FRANCIS & COMPANY**  
CONSULTING ENGINEERS





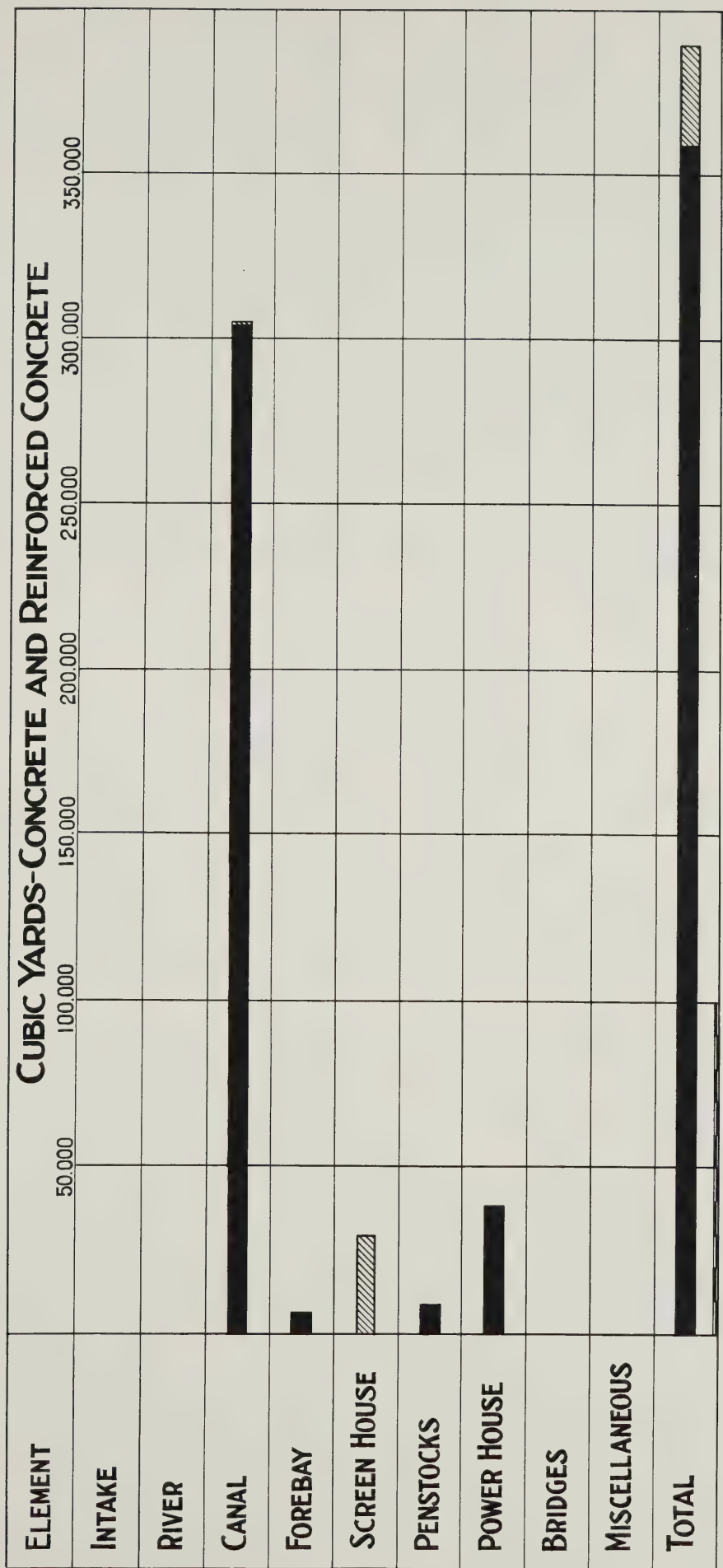


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**DISTRIBUTION CHART  
OF ROCK EXCAVATION  
IN CANAL AND FOREBAY**  
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CUBIC YARDS-CONCRETE AND REINFORCED CONCRETE



CONCRETE  
REINFORCED CONCRETE

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DISTRIBUTION CHART  
OF CONCRETE WORK  
IN CANAL AND FOREBAY  
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yards were placed in the canal section. The relative importance of the canal section proper is, therefore, apparent and when reading the later sections of our report this fact should be kept in mind. We will deal later in detail with the rate of progress on the various parts of the work, but we include herewith as pages 125, 126 and 127 progress charts showing the rate at which the earth and rock excavation and concrete work was done during the entire period of construction.

#### Section 24

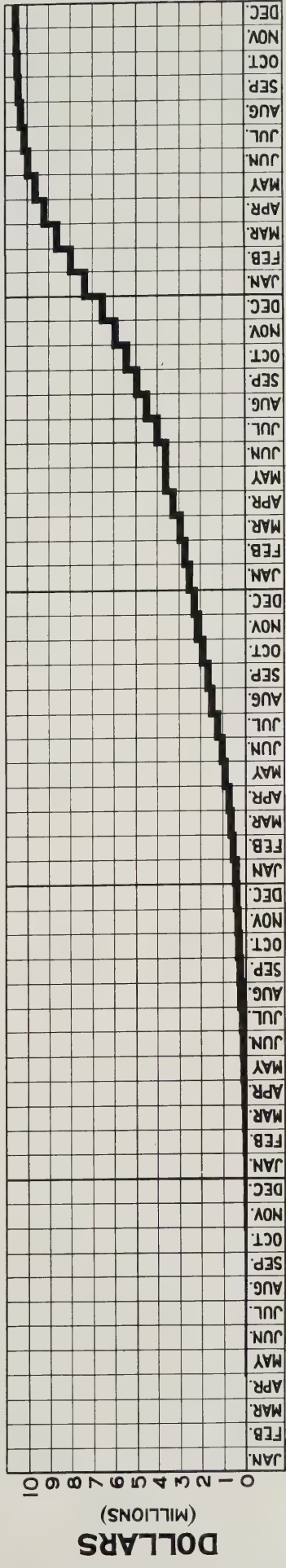
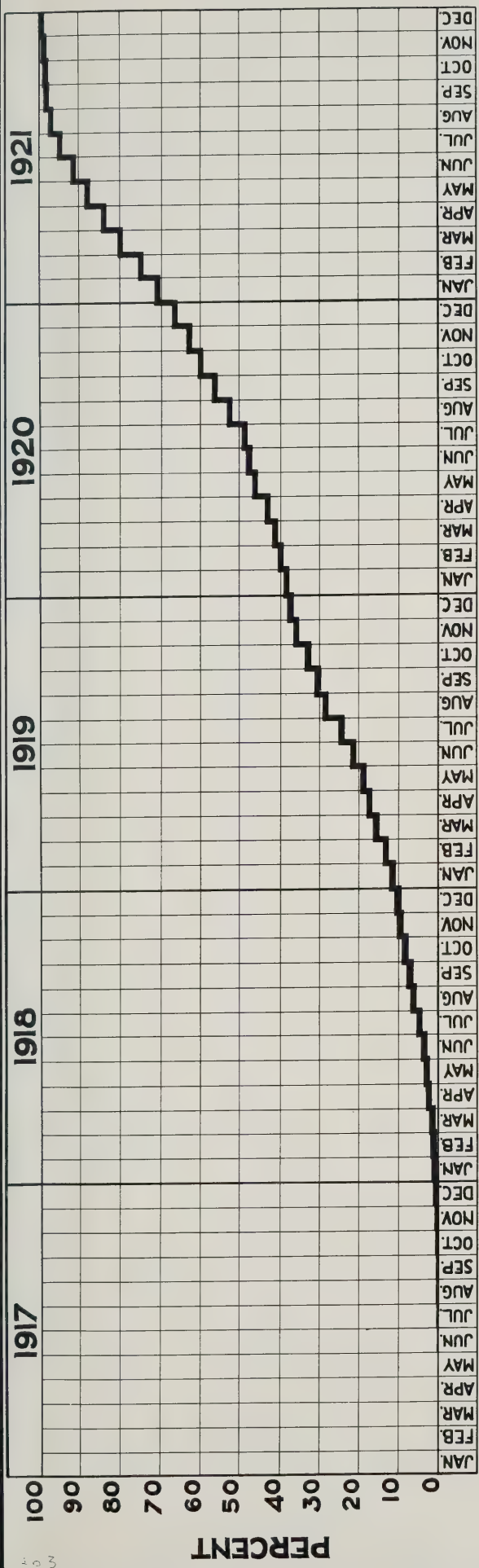
#### SUMMARY OF COSTS

As previously stated our Consulting Engineer has prepared a report entitled "Chapter I - Costs, Analysis of Expenditures to March 31, 1922". This document deals in a most comprehensive and detailed way with all of the expenditures made on the work and almost any detail desired may be obtained by referring to it.

On page 128 we include a diagram showing the total expenditure on the project to March 31st, 1922. From this diagram it will be noted that the costs as at that date amount to a net total of \$62,182,623.65 which total is subdivided under seventeen main headings. The striking feature about this diagram is that it shows the relative importance of the expenditure made on the canal proper in comparison with the whole Development. Out of a total of over \$62,000,000 nearly \$36,000,000 was expended on this portion of the work.



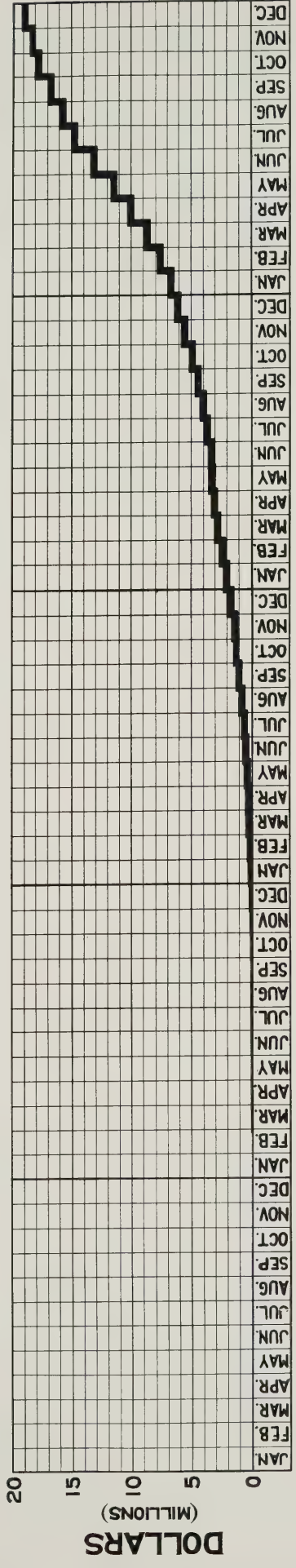
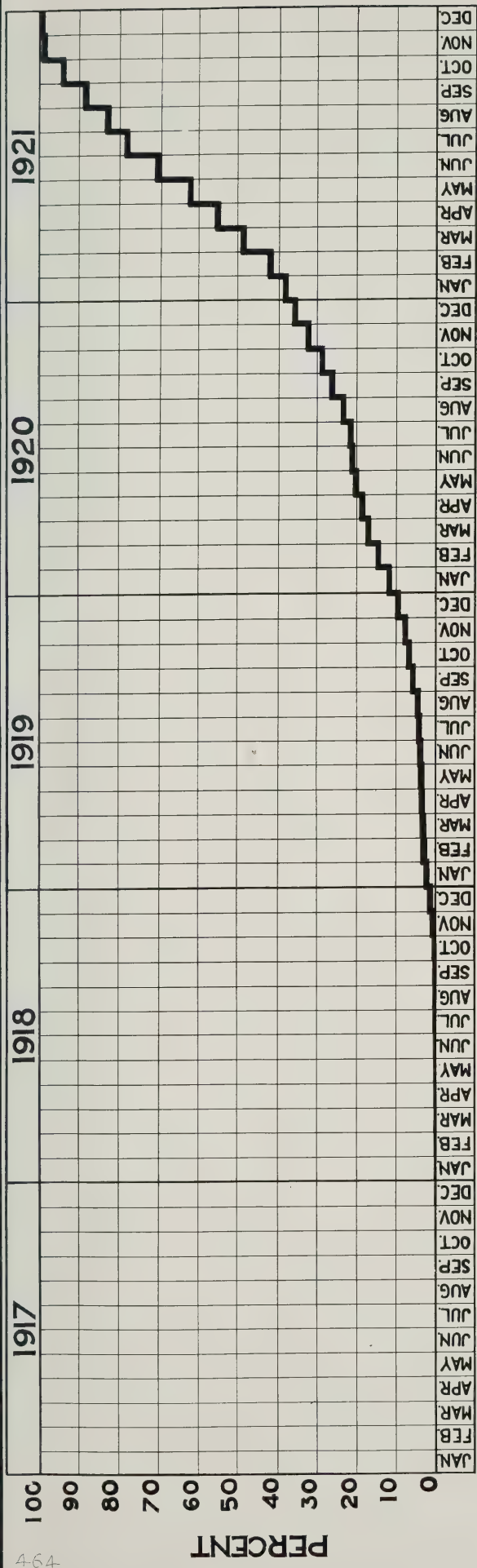




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**PROGRESS CHART FOR EARTH EXCAVATION  
IN INTAKE, CANAL, FOREBAY AND POWER HOUSE**  
Toronto, May 3rd, 1923. Made by *W.D.G.*, Checked by *W.D.G.*  
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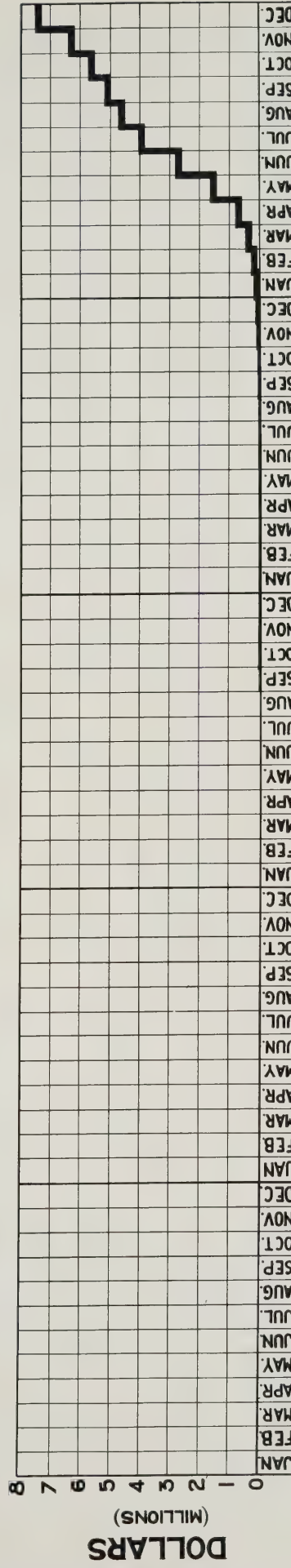
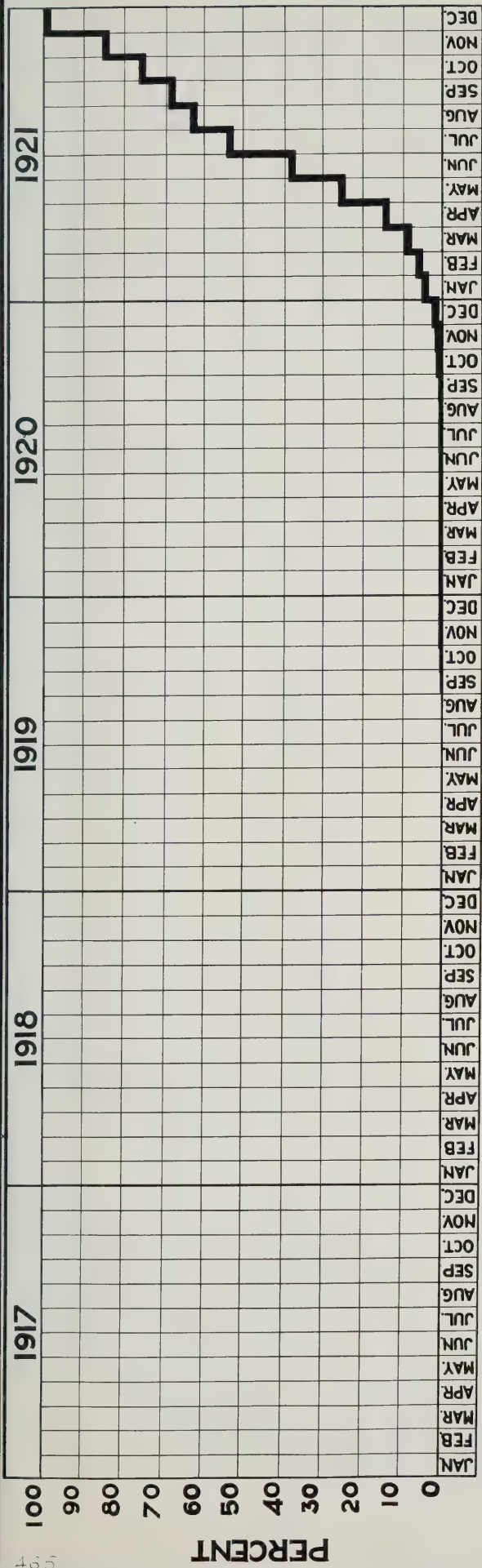




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**PROGRESS CHART FOR ROCK EXCAVATION  
 IN CANAL, FOREBAY AND POWERHOUSE**  
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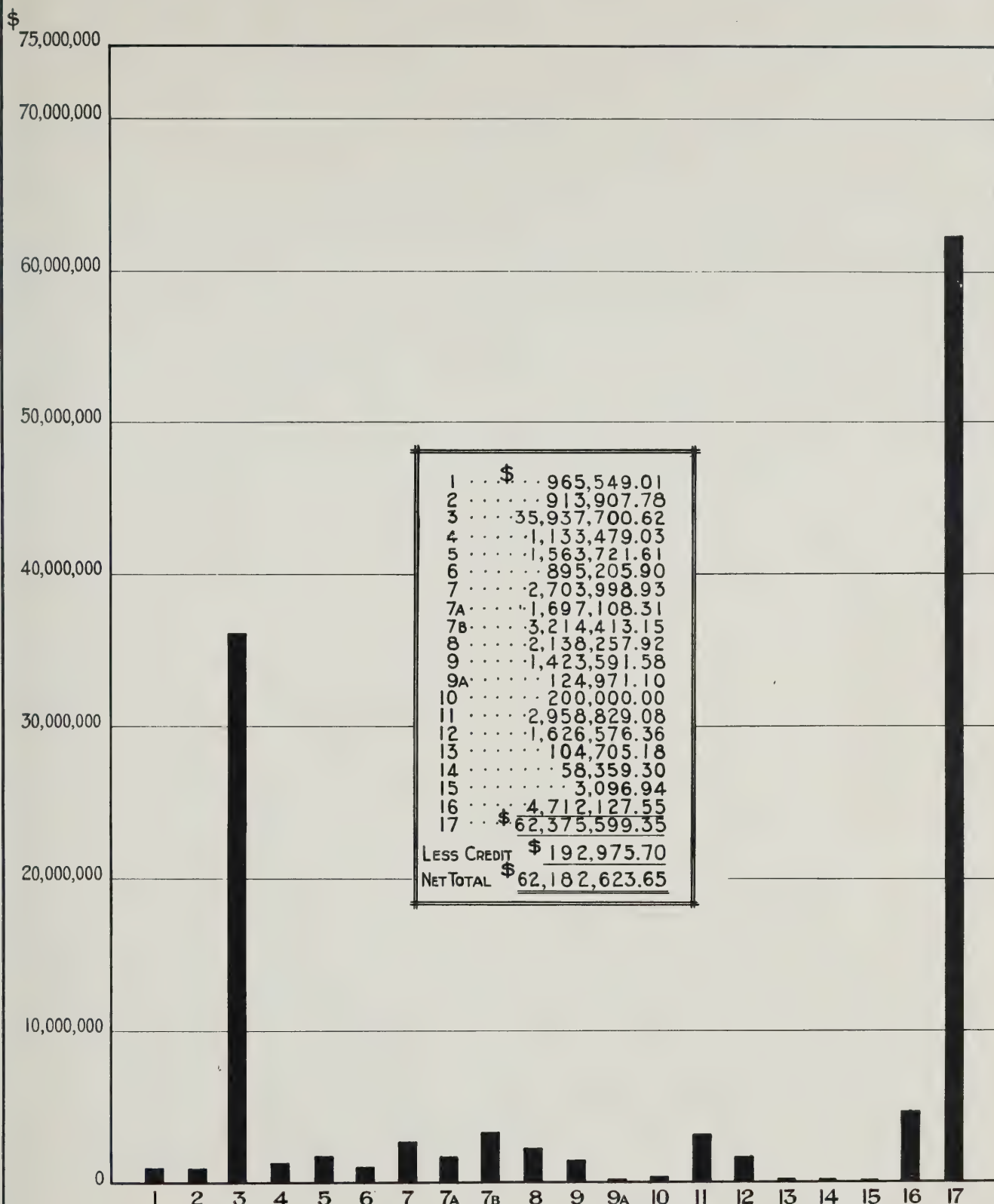




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PROGRESS CHART FOR CONCRETE WORK  
IN CANAL AND FOREBAY  
Toronto, May 3rd, 1923. Made by *W.D.* Checked by *W.D.*  
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CONSULTING ENGINEERS







- |                          |                             |
|--------------------------|-----------------------------|
| 1 INTAKE                 | 9 RIGHT-OF-WAY              |
| 2 RIVER                  | 9A MISCELLANEOUS            |
| 3 CANAL                  | 10 QUEENSTON-POWER HOUSE RY |
| 4 FOREBAY                | 11 PLANT SALVAGE            |
| 5 SCREEN HOUSE           | 12 STORES                   |
| 6 PENSTOCKS              | 13 EXPENDITURES             |
| 7 POWER HOUSE            | 14 SALES AND WORK ORDERS    |
| 7A HYDRAULIC MACHINERY   | 15 SUSPENSE ACCOUNT         |
| 7B ELECTRICAL GENERATION | 16 BOND INTEREST            |
| 8 BRIDGES                | 17 GROSS TOTAL COST         |

HYDRO-ELECTRIC INQUIRY COMMISSION  
W.D.GREGORY, CHAIRMAN  
QUEENSTON-CHIPPAWA POWER DEVELOPMENT  
COST BY CONSTRUCTION ELEMENTS  
**TOTAL EXPENDITURE ON PROJECT**  
TO MARCH 31st 1922  
Toronto, May 2nd., 1923, Made by *WJF* Checked by *WJF*  
WALTER J. FRANCIS & COMPANY  
CONSULTING ENGINEERS





In view of the fact that the Commission in carrying out this work itself, had necessarily to include items for owner's overheads and financing costs, in addition to overhead costs and construction interest which would be incidental to a contractor's cost, if the work had been let by contract, our Consulting Engineer has made an analysis giving the final unit costs of the principal items of the work, namely earth excavation and rock excavation and concrete on two basis which may be termed "Contractor's Cost" and "Owner's Cost". In dealing with this matter the following paragraph and table of unit costs are included direct from our Consulting Engineer's report, pages K-104 and K-105:

"The (following) analysis gives the unit costs derived from a consideration of the quantities for the principal classifications of work and the total costs thereof, first, on the usual basis of the costs to a general contractor carrying out the work, and, second, to the owner by the addition of the administrative field overhead and the head office overhead costs not ordinarily borne by a contractor. The first case is given in dollars per cubic yard of completed work in the column marked 'A' below, which embraces 'Direct Costs', 'Field Service Costs' and 'Field Overhead Costs' .....; while the second case is given in similar terms in the column marked 'B', which in addition to the costs contained in column 'A' embraces 'Administrative Field Overhead Costs' and 'Head Office Overhead Costs' ....."



In view of the fact that the Commission in carrying out this work itself, had necessarily to include items for owner's overheads and planning costs, in addition to increased costs and construction interest which would be included in a contractor's cost, if the work had been let by contract, our Committee believed that some estimate giving the total cost of the project at this time, would, usually, have been made and would have been made on the basis of the cost of the work at the time of the estimate. In dealing with this matter the Committee has

The following analysis gives the unit costs derived from a consideration of the quantities for the principal classifications of work and the total costs thereof, first, on the usual basis of the cost to a Government contractor, and second, on the basis of the cost to the Government.

In the case of the addition of the administrative staff overhead and the same office overhead costs not ordinarily borne by a contractor. The first case is given in dollars per cubic yard of completed work in the column marked 'A' below, which embraces 'first cost', 'first cost plus profit' and 'first cost plus overhead'.

While the second case is given in similar terms in the column marked 'B', which in addition to the first cost includes in item 'A' overheads, 'first cost plus profit' and 'first cost plus overhead'.

## HYDRO-ELECTRIC INQUIRY COMMISSION

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## Derived Unit Costs of the Principal Classifications of Work

Work and Location of Same	Unit Costs in Dollars per Cubic Yard	
	Column "A" "Contractor's Cost"	Column "B" "Owner's Cost"
<b>Earth Excavation Work:</b>		
Intake .....	\$0.7645	\$0.8059
Welland River .....	0.7178	0.7559
Canal .....	0.8087	0.8504
Canal Dredging .....	0.7566	0.7852
Forebay .....	0.5056	0.5301
Screen House .....	1.2646	1.3174
Power House .....	0.8762	0.9316
Average of all Earth Excavation Work .....	0.7924	0.8325
<b>Rock Excavation Work:</b>		
Canal .....	3.5635	3.7580
Forebay .....	1.6829	1.7611
Screen House .....	3.6786	3.8805
Penstocks .....	9.3516	9.9128
Power House .....	3.2512	3.5196
Average of all Rock Excavation Work .....	3.3752	3.5647
<b>Concrete Work:</b>		
<b>Plain Concrete:</b>		
Canal Lining .....	21.5296	22.9704
Forebay .....	28.0318	30.3328
Penstocks .....	19.8362	22.0369
Power House .....	30.1969	33.7597
Average of all Plain Concrete Work .....	22.5370	24.2412
<b>Reinforced Concrete:</b>		
Screen House .....	35.2118	38.8018
Average of all Reinforced Concrete Work .....	35.2118	38.8018

The relationship that these actual costs bear to the costs estimated by the Commission's engineers in estimates prepared by them from



Percent of total weight of the material in the sample

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Percent of total weight of the material in the sample

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100.0000	100.0000	100.0000
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100.0000	100.0000	100.0000

The following table shows the results of the analysis of the sample

The following table shows the results of the analysis of the sample

time to time will be discussed in detail later in this report, but they are given here as a matter of record as they come within the subject of "Analysis of Expenditures".

#### Total Cost to complete

Out of the general question of costs naturally arises a discussion as to what will be the ultimate cost of the whole Development, when completed. In this connection the question referred to this Commission in the Letters Patent, being No. 3, reads as follows:

"The total cost when completed of the Queenston-Chippawa Power Development."

(a) With five units installed.

(b) With units installed to the full capacity of the canal.

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In giving an answer to question No. 3, it is to be borne in mind that any figure submitted is necessarily the result of the compilation of an estimate based upon expenditures already made and an estimate of the cost of what will be required to complete the work yet to be undertaken. The figures herewith submitted then, cannot be taken as an exact representation of cost, but our Consulting Engineer has carefully examined the work yet to be completed and has satisfied himself that these figures represent as nearly as possible, actual cost.

#### Answer to Question 3(a)

The total cost of the Queenston-Chippawa Power Development up to the completion of five units as nearly as can be determined is \$63,654,295.49. This figure includes the whole of the completed canal and the intake as well as other portions of the Development which will be used in conjunction with the units to be subsequently installed. It is impossible to subdivide



time to time will be necessary to keep in this country, and may  
 be done in a number of ways, as follows: the subject of

"Analysis of the subject."

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the work so as to make the cost applicable to the five units only. Unit costs such as capital cost per horse-power, cannot be definitely derived from the above figures, and are obtainable only by considering the total cost of the fully completed Development.

Answer to Question 3(b)

The estimated cost of the Queenston-Chippawa Power Development with units installed to the full capacity of the canal is \$82,483,914.00. This figure is derived by considering the expenditures made to date, adding thereto the estimated cost for completion and deducting therefrom the estimated salvage value of the construction plant, stores on hand and so forth, but not deducting anything for lands purchased over and above present requirements.

The expenditures in connection with the Development up to September 30th, 1923, including \$2,019.14 for investigation for future development, as shown by the records of the Commission is \$66,796,811.53 after making deduction for the estimated salvage. The total is arrived at by completed records up to August 31st, 1923, amounting to \$66,578,811.53, together with estimated expenditures during September 1923 amounting to \$417,000.00.

Memo  
by  
WJF.

The work on the new machine is the first of its kind. This work is being done by the new machine, which is being built by the new machine. The new machine is being built by the new machine. The new machine is being built by the new machine.

Amount in Dollars (\$)

The estimated cost of the new machine is \$10,000.00. This cost is being paid by the new machine. The new machine is being built by the new machine. The new machine is being built by the new machine. The new machine is being built by the new machine.

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WaterPART VI - CAPACITY OF DEVELOPMENTSection 25GENERAL

In Section 24 we have dealt with the question of capital expenditures, and have indicated what the total cost of the Development will be when completed. The cost of the Development and its capacity are more or less complementary to each other and the two must be considered together if the true economics of the Development are to be understood.

In order to submit reliable information relative to the actual capacity of the Development and the power which would be made available with the plant in operation, our Consulting Engineer was instructed to determine, as closely as possible, the carrying capacity of the canal and the actual output of electrical energy available from the units at present installed, and from this information to derive, as closely as possible, the commercial output of the plant under various conditions. In connection with this matter, Mr. Walter J. Francis has prepared an exhaustive report entitled "Chapter D - Power Available". His studies on the subject are comprehensive and in addition to carrying on actual tests of the plant as now in operation, conducting measurements and making physical examination and hydraulic studies of the several elements constituting the Development, he has carefully examined meteorological and other data available from the records of the plants which have been in operation over a great number of years.



# SECTION 10 - SECURITY INFORMATION

## 10.1 - SECURITY INFORMATION

### 10.1.1 - SECURITY INFORMATION

In Section 10 we have dealt with the question of capital ex-

penditure, and have indicated that the total cost of the investment will be about \$100 million. The cost of the investment and the operating costs are shown in Table 10.1. The operating costs are shown in Table 10.2. The total cost of the investment and the operating costs are shown in Table 10.3.

It has been estimated that the investment and the operating costs are shown in Table 10.3.

It is to be noted that the investment and the operating costs are shown in Table 10.3.

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The determination of the power available from the Development involves primarily the determination of the elevation of the head waters, the carrying capacity of the Welland River, the carrying capacity of the canal, the determination of the elevation of the tail water, and the efficiency of the main units. In addition to these principal features, many minor hydraulic losses have to be considered, as, for example, the entrance head of the intake, the losses due to bends and to changes of section in the river and in the canal, the loss in entrance head at the screen house, the loss in the penstocks and in the Johnson valves, and in the draft tubes, as well as the losses in the turbines and in the electrical equipment.

WJF.  
D-1.

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The determination of available power for a given hydro-electric development generally includes amongst other factors watershed area, precipitation, evaporation and run-off, in order to arrive at the dependable flow, but none of the four enter into the problem in the usual way in connection with the Queenston-Chippawa Power Development. Lake Erie constitutes the immediate head water, and the discharge of the Great Lakes System down to and including Lake Erie, being the Niagara River, is the source of water supply for the Development. The proportion of water available for this and other developments is derived from the terms of an international agreement. Our Consulting Engineer states that, in his opinion, it is possible that the quantity of water divertible from the Niagara River for hydro-electric purposes may be increased in the near future by mutual consent of Canada and the United States, and that, in view of the advantages that would accrue, the elevation of the water surface, at which the diversion may be made, will be held more nearly constant or raised above the elevation

WJF.  
D-2







now generally obtaining.

The Development is well located to take advantage of any future regulation in this respect and it is also advantageously situated in having its tailrace so closely adjacent to Lake Ontario. In connection with this particular matter, our Consulting Engineer states:

"These features, briefly summed up as fixed and dependable elevations of head water and tail water, as well as definite flow, taken in conjunction, make the location of the Queenston-Chippawa Power Development highly advantageous from the viewpoint of hydraulics."

WJF.  
D-2

After describing the manner in which the data and results contained in the report referred to above were obtained, our Consulting Engineer states as follows:

"Taken as a whole, the results in the present volume under the general title of 'Power Available' have been obtained after a practically continuous study during sixteen months, followed as quickly as the exigencies of the situation would permit."

WJF.  
D-3

#### Section 26

#### CAPACITY OF THE DEVELOPMENT

The general question referred to this Commission in connection with the above subject, being Question No. 4, is:

"The continuous output capacity of the Queenston-Chippawa Power Development, under the conditions mentioned in Clause 3."

Clause 3 referred to is Question 3 contained in the Letters Patent, and the conditions referred to are Parts (a) and (b) of Question 3, which are as follows:

- (a) With five units installed.
- (b) With units installed to the full capacity of the canal.

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Capacity with Five Units Installed

To this part of question No. 4 based upon the tests and studies which are recorded in our Consulting Engineer's report before referred to, the answer is:

"The continuous twenty-four hour output capacity of the Queenston-Chippawa Power Development with five units installed under normal operating conditions is 275,000 electrical horse-power."

Capacity with Units Installed  
to Full Capacity of the Canal

On the same basis as Question 4(a), answered above, the following statement is submitted in answer to Question 4(b):

"The estimated continuous twenty-four hour output capacity of the Queenston-Chippawa Power Development with units installed to the full capacity of the canal is 550,000 electrical horse-power."

Section 27WATER AVAILABLE FOR DEVELOPMENT

A discussion of this question necessarily includes consideration of the conditions under which the Development will be operated by the Commission. As we have already shown in our report on the Niagara System, the Commission, in addition to the plant at Queenston, owns and operates two other large plants which also draw their water from the Niagara River, namely, the plants of The Ontario Power Company and the Electrical Development Company. Therefore, it is necessary to consider the operation of the Queenston-Chippawa plant not only as a unit by itself, but as one operated in conjunction with the two other plants just named.

The combined operations of these plants is fully discussed in



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REMARKS OF THE SECRETARY

It has been the privilege of the Secretary to have the honor of introducing to the members of the Board of Engineers and Architects the report of the Board of Engineers and Architects for the year 1900.

The report for

The Board of Engineers and Architects for the year 1900, which was presented to the Board of Engineers and Architects on the 15th of December, 1900, and which was approved by the Board of Engineers and Architects on the 15th of December, 1900.

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our Consulting Engineer's report entitled "Niagara System, Part II", and the matter is further discussed in this Commission's report entitled "Report on the Niagara System" and for detailed information we would refer you to these documents. In this report we will deal only with the broader question, namely, the water that is available for the Queenston-Chippawa plant under normal operating conditions and the power that can be developed from it.

The Letters Patent refers to this matter in Question 6, which reads:

6. (a) The quantity of water now available for use by means of the Queenston-Chippawa Canal;
- (b) The power that can be developed thereby in continuous output at the Queenston Power Station.

(a) The Quantity of Water now Available

The water now available for use by means of the Queenston-Chippawa Canal is derived from two sources, namely, the Welland River and the Niagara River.

The flow of the Welland River is comparatively small, and the consensus of opinion is that it may be considered to be less than 100 cubic feet per second at low water. The engineers of the Commission in their estimates used the figure of 50 cubic feet per second as the available flow from the Welland River, without allowing for its storage possibilities as pondage for a daily regulator in power plant operation.

The flow from the Niagara River is limited by the provisions of a treaty ratified May 5th, 1910, between Great Britain and the United States,





which treaty was to remain in force for five years, terminable thereafter on twelve months written notice by either party. No notice of termination has been given. Paragraph 4 of Article V of the Treaty says:

"The United Kingdom or the Dominion of Canada, or the Province of Ontario, may authorize and permit the diversion within the Province of Ontario of the waters of said River above the Falls of Niagara, for power purposes, not exceeding in the aggregate a daily diversion at the rate of 36,000 cubic feet of water per second."



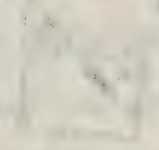
This paragraph apparently contemplates a variation in the rate of use of water for power purposes throughout different periods of the same day. This is in accordance with the usual practice of all hydro-electric power plants, wherein the rate of use of water varies throughout the twenty-four hours according to the load demands upon the plant. While it would be evidently unreasonable to interpret this clause as permitting the diversion of water at a rate four or five times the figure specified during a few hours of the day, it is quite reasonable, on the other hand, to permit of variations in the rate of use so as to conform with the ordinary conditions found in plants at Niagara Falls. The limits of variation in the rate of use of water differs from plant to plant, but a variation of 20% or even 25% above the average stated by the treaty is well within the bounds of reasonable interpretation. Such an interpretation would permit a total diversion on the Canadian side of the Niagara River for power purposes up to a figure of about 45,000 cubic feet per second during several hours of each day, provided the total diversion did not exceed "in the aggregate a daily diversion at the rate of 36,000 cubic feet of water per second."

The four existing hydro-electric power plants on the Canadian



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which twenty are to remain in force for five years, terminating thereafter  
 as before except with notice by either party. No notice of termination  
 was given. Paragraph 4 of Article I of the Treaty reads:



"The United States on the Pacific of Canada, as the  
 Province of Ontario, may maintain and control the  
 division within the Province of Ontario of the waters  
 of said River above the Falls of Niagara, the same  
 division, and according to the aggregate daily  
 quantity of the water of said River to be used  
 for power."

This paragraph apparently contemplated a variation in the rate  
 of use of water for power purposes throughout different periods of the year.  
 But, this is in accordance with the usual practice of all hydro-electric

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power plants, wherein the rate of use of water varies throughout the year.  
 The power companies of the United States and the British Empire have  
 voluntarily agreed to observe this clause in partitioning the division

of water as a part of the plan for the electric power supply in the  
 Great Lakes. It is further understood, as the other facts in regard to  
 variations in the rate of use of water are in evidence, that the same should not

be used in plants at Niagara Falls. The limits of variation in the rate of use  
 of water between these plants is fixed, but a variation of 10% or over the above  
 the amount stated by the treaty is well within the bounds of reasonable

interpretation. Such an interpretation would permit a total diversion on  
 the Canadian side of the Niagara River for power purposes up to a figure of  
 about 15,000 cubic feet per second during several hours of each day, pro-

vided the total diversion did not exceed "in the aggregate a daily diversion  
 of the rate of 15,000 cubic feet of water per second."

The fact that the power companies of the United States and the Canadian

side of the Niagara River, exclusive of the Queenston-Chippawa Power Development, were diverting under ordinary use, before the Queenston-Chippawa Power Development was built, an aggregate amount of 32,000 or 33,000 cubic feet of water per second, as nearly as can be determined. The Commission now owns or controls the Electrical Development Company plant and The Ontario Power Company plant, thus obtaining the opportunity of working these two plants in conjunction with the Queenston-Chippawa Power Development. The other two power plants, namely, the Canadian Niagara Power Company and the International Railway Company have water rights which are fixed by agreement and Orders-in-Council, so that the use of water by these two plants is defined and limited, but it is not under the control of the Commission. The maximum amount of water usable by these two plants together is variously estimated between 8,500 cubic feet per second and 9,800 cubic feet per second.

It is estimated that the most efficient use by the Commission of the Electrical Development Company plant and The Ontario Power Company plant would be at a combined output of about 250,000 electrical horsepower continuously, requiring an amount of water variously estimated between 17,200 cubic feet per second and 18,100 cubic feet per second.

With all four plants in operation under these circumstances the probable use of water is about 26,000 or 27,000 cubic feet per second. Deducting 27,000 cubic feet of water per second from the figure derived from the above interpretation of the provisions of the treaty, it is evident that about 18,000 cubic feet per second should be available for the operation of the Queenston-Chippawa Power Development.





While not specifically referred to in any of the questions referred to this Commission in the Letters Patent, it is to be noted that the plant as at present built, and more particularly the canal, was designed to utilize 15,000 cubic feet of water per second. Tests conducted by our Consulting Engineer indicate that the expectations of the Commission's engineers in this respect will be exceeded and that it may be safely assumed that the canal will pass a flow of water totalling 16,000 cubic feet of water per second or more. It is apparent, therefore, that the canal is capable of passing the maximum amount of water, which our Consulting Engineer states should be available for the operation of the plant.

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In discussing this matter, it is to be borne in mind that the statements just previously made largely depend upon what may be termed a practical interpretation of the terms of the treaty covering the diversion of water from the Niagara River. But no matter what the interpretation of the provisions of the agreement may be, it is to be remembered that even though the amount of water allotted to Canada be restricted to an overall maximum of 36,000 cubic feet of water per second, the Commission owning and operating The Ontario Power Company and the Electrical Development Company may, at its discretion, restrict the operation of these plants and utilize the water thus made available for the Queenston-Chippawa plant. It may be said, therefore, that the Commission is in a position to make sufficient water available for the full and complete operation of the Queenston-Chippawa plant, by regulating the operation of the two older plants. It seems reasonable to assume that it will follow this course, for not only has





the Queenston-Chippawa plant a very high operating efficiency as compared with the older plants, but one cubic foot of water used at the high head available at Queenston will develop twice as much power as the head available at the other plants.

The  
100%  
advantage

Power that can be Developed by 18,000  
cubic feet of water per second

The second part of Question 6 has already been dealt with in our answer to Question 4, but for the sake of completeness the following statement is submitted again. The power that can be developed by 18,000 cubic feet of water per second in continuous output at the Queenston-Chippawa Power Station is 550,000 electrical horse-power.

**COPY** Section 22

COST OF POWER DEVELOPED

The Letters Patent refers to this matter in Question No. 7 which is:

"In what manner and to what extent will the price of Niagara Power be affected, if at all, by the cost of the Queenston-Chippawa Development."

The Queenston-Chippawa Power Development commenced to deliver power to the Niagara System early in 1922, although undergoing adjustment and extension. In the same year the Commission took over the Toronto Power Company, including the plant of the Electrical Development Company and a steam plant in Toronto. In the same year the Commission decided to operate the plant of The Ontario Power Company "at cost", rather than to follow the former procedure of billing themselves with part of the power at the old contract rate and making a supplementary charge to cover the loss on the contract price.



The Government-Channel Grant a very high percentage of efficiency in use.

Based with the other plants, but one cubic foot of water used at the

high head available at Government will develop more or less power as the

head available at the other plants.

Power that can be developed by 15,000

horse power is about 15,000

The amount of power at the other plants is not always the same as at the

one shown in Exhibit 1, but for the sake of comparison the following

assumptions are made: (a) The power that can be developed by 15,000

horse power is about 15,000

horse power is about 15,000

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and the other plants.

The balance of power is not shown in Exhibit 1.

which is

It is not shown and is not shown with the power at the

other plants.

The Government-Channel Grant Development is shown in Exhibit

1, showing the power at the other plants.

and Exhibit 1. It is not shown the power at the other plants.

showing the power at the other plants.

showing the power at the other plants.

showing the power at the other plants.

showing the power at the other plants.

showing the power at the other plants.

showing the power at the other plants.

showing the power at the other plants.

Taking all these factors into consideration, it is evident that 1922 is a transition year. Several years may elapse before the whole combination of power plants will have reached a condition of stability as regards costs and operating conditions. Therefore the comparison of power prices must be made with the end of 1921 as the dividing line, the period prior to that date being before the Queenston-Chippawa Power Development was sufficiently far advanced to be considered as a power producer.

The average price which the Commission paid for Niagara power from all sources of supply from 1911 to 1921, inclusive, is as follows: 1911, \$9.40; 1912, \$9.37; 1913, \$9.00; 1914, \$9.00; 1915, \$9.00; 1916, \$9.46; 1917, \$10.11; 1918, \$10.07; 1919, \$10.25; 1920, \$11.36; 1921, \$12.55. All the figures are in dollars per horse-power purchased per annum. In 1922 the average cost is stated to have been \$16.55 per horse-power per annum, but this figure includes a block of 73,966 horse-power from the Queenston-Chippawa Power Development, billed at the arbitrary figure of \$20.00 per horse-power per annum.

To find the effect of the Development on the price of Niagara power it is necessary to estimate the cost of power from each of the three sources of supply at Niagara Falls, namely The Ontario Power Company plant, the Electrical Development Company plant and the Queenston-Chippawa Power Development, and to ascertain the proportion of the total power demand supplied from each of the three sources.

The output capacity of The Ontario Power Company plant under maximum conditions is about 193,000 horse-power, but the probable most





efficient point of operation is with an output of about 150,000 horse-power. Similarly, the Electrical Development Company plant could produce about 145,000 horse-power, but its probable most efficient use is at an output of about 100,000 horse-power. There is also the steam reserve plant at Toronto, which although not operating is being maintained as an emergency power reserve, and the fixed charges should be billed against power generation.

The cost of Niagara power at the switchboard at Niagara Falls will be made up in the future of the operating costs and fixed charges on the four power generating plants above mentioned.

Assuming a fixed output of 250,000 horse-power under normal conditions from the combined operation of The Ontario Power Company plant and the Electrical Development Company plant, the balance of the demand being supplied from the Queenston-Chippawa Power Development, the figures are as follows:

(1) The Ontario Power Company Plant

Total annual operating costs and fixed charges, between (a) \$2,000,000 and (b) \$2,200,000, equivalent respectively to \$13.50 and \$15.00 per horse-power per annum, with an output of 150,000 horse-power.

(2) Electrical Development Company Plant

Total annual operating costs and fixed charges, between (a) \$1,200,000 and (b) \$1,300,000, equivalent respectively to \$12.00 and \$13.00 per horse-power per annum, with an output of 100,000 horse-power.

\$2,000,000	\$2,100,000	\$2,200,000	\$13.50	\$15.00
\$2,100,000	\$2,200,000	\$2,300,000	\$14.00	\$15.50
\$2,200,000	\$2,300,000	\$2,400,000	\$14.50	\$16.00
\$2,300,000	\$2,400,000	\$2,500,000	\$15.00	\$16.50
\$2,400,000	\$2,500,000	\$2,600,000	\$15.50	\$17.00
\$2,500,000	\$2,600,000	\$2,700,000	\$16.00	\$17.50
\$2,600,000	\$2,700,000	\$2,800,000	\$16.50	\$18.00
\$2,700,000	\$2,800,000	\$2,900,000	\$17.00	\$18.50
\$2,800,000	\$2,900,000	\$3,000,000	\$17.50	\$19.00



estimated point of completion is with an output of about 100,000 horsepower. Similarly, the Electrical Development Company plant will produce about 100,000 horsepower, and the Hydroelectric plant will produce about 100,000 horsepower. There is also the steam plant at Denver, which although not completed is being retained as an emergency power source, and the third major plant is still being planned.

The cost of electric power in the neighborhood of \$100 per kilowatt hour will be made up in the future of the operating costs and fixed charges on the new power generating plants after completion.

Estimated annual output of 100,000 horsepower under normal

conditions from the various sources of the electric power system and the Electrical Development Company plant, the balance of the demand being supplied from the American-Hydroelectric power development, the figures are as follows:

(1) The Electric Power Company Plant

Total annual generating capacity and fixed charges, before  
(a) 100,000 and 100,000, equivalent respectively to  
100,000 and 100,000 horsepower per annum, with an output of  
100,000 horsepower.

(2) Electrical Development Company Plant

Total annual generating capacity and fixed charges, before  
(a) 100,000 and 100,000, equivalent respectively to  
100,000 and 100,000 horsepower per annum, with an output of  
100,000 horsepower.

(3) Queenston-Chippawa Power Development

Maximum Plant Output, H. P. (No spare machines)	Annual Operating Costs and Fixed Charges		Cost per H. P. per Annua	
	Possible	Possible	Possible	Possible
	Minimum (a)	Maximum (b)	Minimum	Maximum
300,000	\$4,300,000	\$4,450,000	\$14.30	\$14.85
350,000	4,500,000	4,750,000	12.85	13.60
400,000	4,750,000	5,100,000	11.90	12.75
450,000	5,200,000	5,500,000	11.55	12.25
500,000	5,800,000	6,150,000	11.60	12.30
550,000	6,500,000	6,900,000	11.80	12.55

In the above tables the mark (a) denotes estimates based on figures of the Hydro-Electric Power Commission, and the mark (b) denotes figures in which allowances have been made for contingencies, additional reserve for renewals, and so forth, sufficient to cover maximum requirements.

(4) Toronto Steam Plant

The total annual fixed charges should probably be between \$120,000 and \$150,000 annually without output and under normal conditions.

On the above assumptions the weighted average cost of Niagara power at the switchboard at Niagara Falls will be between the following limits:

Combined Output H.P. (all plants)	Total Annual Operating Costs and Fixed Charges		Annual Cost of Power per Horse-Power	
	Possible	Possible	Possible	Possible
	Minimum (a)	Maximum (b)	Minimum	Maximum
550,000	\$7,620,000	\$8,100,000	\$13.90	\$14.75
600,000	7,820,000	8,400,000	13.05	14.00
650,000	8,070,000	8,750,000	12.40	13.45
700,000	8,520,000	9,150,000	12.15	13.10
750,000	9,120,000	9,800,000	12.15	13.10
800,000	9,820,000	10,550,000	12.30	13.20



# TABLE 1. SUMMARY OF THE DATA FOR THE 1970-1971 FISHING SEASON

Date of catch	Species	Weight (lb)	Length (in)	Sex	Age
10/15/70	Atlantic salmon	12.5	18.0	Male	1
10/22/70	Atlantic salmon	15.0	20.0	Female	2
11/05/70	Atlantic salmon	18.0	22.0	Male	3
11/12/70	Atlantic salmon	20.0	24.0	Female	4
11/19/70	Atlantic salmon	22.0	26.0	Male	5
11/26/70	Atlantic salmon	24.0	28.0	Female	6

The data were collected from the 1970-1971 fishing season.

The data were collected from the 1970-1971 fishing season.

The data were collected from the 1970-1971 fishing season.

The data were collected from the 1970-1971 fishing season.

## TABLE 2. SUMMARY OF THE DATA FOR THE 1972-1973 FISHING SEASON

The data were collected from the 1972-1973 fishing season.

The data were collected from the 1972-1973 fishing season.

The data were collected from the 1972-1973 fishing season.

The data were collected from the 1972-1973 fishing season.

Date of catch	Species	Weight (lb)	Length (in)	Sex	Age
10/15/72	Atlantic salmon	12.5	18.0	Male	1
10/22/72	Atlantic salmon	15.0	20.0	Female	2
11/05/72	Atlantic salmon	18.0	22.0	Male	3
11/12/72	Atlantic salmon	20.0	24.0	Female	4
11/19/72	Atlantic salmon	22.0	26.0	Male	5
11/26/72	Atlantic salmon	24.0	28.0	Female	6

From these figures it will be seen that the price of Niagara power to the Commission after 1921 will be affected very little in one sense, and very materially in another, by the installation of the Development.

The figures from 1911 to 1921, inclusive, show that from 1915 the price has been steadily rising. In 1921 it was \$12.55 per horse-power per annum. Omitting 1922 as the first of the transition years, the figures for which are subject to adjustment, the existing present conditions are next to be considered. These show weighted average costs, with 550,000 horse-power available at best efficiency, ranging between \$13.90 and \$14.75 per horse-power, but as the power generated or billed in 1923 was probably not 550,000 horse-power, but some smaller figure, the total annual costs must be divided by the proper horse-power figure to get the average cost price. If this figure were 300,000 horse-power, the average cost would be about \$25.00, and similarly if it were 400,000 horse-power, the cost price per horse-power would be \$19.00 or \$20.00, and so on for any other figure of output. It is reasonable to assume that the output for the year 1923 will lie between these limits. The figures in the above table apply, therefore, only on the assumption that there is a constant output of 250,000 horse-power from the plant of The Ontario Power Company and from the plant of the Electrical Development Company combined, and that each stage of the Queenston-Chippawa Power Development is fully loaded before capital expenditures on succeeding stages of development are made and the annual charges thereon carried by the revenues from operation.

It appears likely that after 1924 or 1925 this condition may be substantially realized, and that for the later stages of development the



from these figures it will be seen that the price of Niagara

power in the immediate future will be estimated very highly in the market.

and very material in nature, by the introduction of the development.

The figures from 1911 to 1914, inclusive, when the price

the price has been steadily rising. In 1911 it was \$11.00 per kilowatt-hour.

the same. In 1914 it was \$12.00 per kilowatt-hour, the figures

for which are subject to adjustment, the existing present conditions are

and to be considered. These were adjusted between 1911 and 1914.

figures are available in the following table between 1911 and 1914.

per kilowatt-hour, and the price received for power in 1911 was \$11.00.

and \$12.00 per kilowatt-hour, and the price received for power in 1914 was \$12.00.

in 1911 it was \$11.00 per kilowatt-hour, and in 1914 it was \$12.00.

It is also noted that the price received for power in 1911 was \$11.00.

and in 1914 it was \$12.00 per kilowatt-hour, the price received for power in

1911 was \$11.00 per kilowatt-hour, and in 1914 it was \$12.00.

and in 1914 it was \$12.00 per kilowatt-hour, the price received for power in

1911 was \$11.00 per kilowatt-hour, and in 1914 it was \$12.00.

only in the example that there is a material change in the price of power

from the time of the first power being sold to the time of the

Electric Light Company's power being sold, and this was done in the

Electric Light Company's power being sold, and this was done in the

Electric Light Company's power being sold, and this was done in the

Electric Light Company's power being sold, and this was done in the

It appears likely that after 1914 or 1915 the condition may be

materially changed, and that the price of power in 1914 was \$12.00.

weighted average cost price of Niagara Power will be about \$12.50 or \$13.00 per horse-power at the switchboard, or about the same as in 1921. Until this condition will have been realized, the annual costs per horse-power must be found by dividing the total costs by the total horse-power billed.

Another aspect of the situation should also be mentioned. If the Queenston-Chippawa Power Development had not been made it would have been necessary to purchase power or generate it elsewhere to supply the load demands. The records show that the purchase price of power from other sources was increasing after 1916, and that in 1920, 1921 and 1922 the purchase price of power required in excess of existing contract arrangements had reached the figure of \$18.00 per horse-power per annum. Other contracts for power supply from the Canadian Niagara Power Company were made by the Commission for the account of The Ontario Power Company of Niagara Falls, one for 9,000 horse-power for two years ending January 31st, 1922, at \$18.00 per horse-power per annum, and several other contracts aggregating about 30,000 horse-power and discontinued May 31st, 1922, at \$16.20 per horse-power per annum, payable in United States funds, approximating \$18.00 in Canadian funds at the time. After the Queenston-Chippawa Power Development was in operation, a contract to purchase 20,000 horse-power at \$15.00 per horse-power per annum from the Canadian Niagara Power Company was made by the Commission in December, 1922, and this contract will expire on May 1st, 1930. The supply available from such outside sources as the above was not and is not sufficient to serve the needs of the various customers who have since demanded power service. The Queenston-





Chippawa Power Development has supplied the demand, and if the estimated costs are substantially realized in the future, it will show very large savings over the probable price of purchasable power.

By itself, the Development would doubtless produce power in its various stages of development at a cost price of \$14.50 or \$15.00 per horse-power per annum with five units fully loaded, which would be reduced to \$12.00 or \$13.00 per horse-power per annum with the full development operating under normal conditions and free from operating difficulties.

It is evident that The Ontario Power Company plant at 150,000 horse-power output would produce power at \$13.50 to \$15.00 per horse-power per annum based on a capitalization of about \$25,000,000, and that the Electrical Development Company plant at an output of 100,000 horse-power would produce power at \$12.00 or \$13.00 per horse-power per annum based on a capitalization of about \$13,000,000.

With 190,000 horse-power output the costs at The Ontario Power Company plant would be about \$11.00 or \$12.00 per horse-power per annum, and, similarly, if the Electrical Development Company plant were operating with 146,000 horse-power output the costs would be \$6.50 or \$9.00 per horse-power per annum.

If these plants were operated at these outputs, however, the capacity of the Development would be limited to about 350,000 horse-power with the present water rights, and the combined weighted average cost would be from \$11.50 to \$12.25 per horse-power per annum.



There are no other persons named in the report.

1. The first step in the process of the development of a new product is the identification of a market need. This is often done through market research, which can be conducted in a number of ways. One way is to conduct a survey of potential customers, asking them about their needs and preferences. Another way is to observe the behavior of potential customers in a retail environment. A third way is to analyze the sales data of existing products to identify gaps in the market.

It is believed that the Central Power Company plant at Elk, Wyo., has a capacity of about 150,000 kilowatts. The plant is owned by the Central Power Company, which is a subsidiary of the United States Steel Corporation. The plant is located in the State of Wyoming, and is one of the largest power plants in the West. The plant is owned by the Central Power Company, which is a subsidiary of the United States Steel Corporation. The plant is located in the State of Wyoming, and is one of the largest power plants in the West.

1. The first step in the process of developing a new product is to identify a market need. This is often done through market research, which can be conducted in a number of ways. One common method is to conduct surveys of potential customers, asking them about their needs and preferences. Another method is to observe how people use existing products and identify areas for improvement. A third method is to consult with experts in the field, such as scientists or engineers, who can provide insights into new technologies and their potential applications.

It was found that the results of the investigation were similar to those obtained from the other two investigations.

Assuming unrestricted water rights for the present plants with full capacity installed, 27,000 cubic feet of water per second would produce about 340,000 horse-power from The Ontario Power Company plant and the Electrical Development Company plant combined, at a total annual cost between \$3,400,000 and \$3,600,000, these total figures being equivalent to \$10.00 per horse-power per annum, and \$11.20 per horse-power per annum, respectively. The Queenston-Chippawa Power Development could probably produce 550,000 horse-power with 18,000 cubic feet per second of water at a cost of \$12.00 or \$13.00 per horse-power per annum. The weighted average of these figures would be about 900,000 horse-power at \$11.00 to \$12.00 per horse-power per annum, and the total water required for these three plants would be about 45,000 cubic feet per second. Adding the water used by the Canadian Niagara Power Company and by the International Railway Company, the total water diversion on the Canadian side would have to be about 55,000 cubic feet per second and the total power produced would be about 1,000,000 horse-power.

#### Other Factors Affecting Cost of Power

The foregoing statement is what may be termed a comprehensive answer to Question No. 7 contained in the Letters Patent and the figures quoted have, in the first instance, been arrived at by using estimates submitted to our Consulting Engineer by the engineers of the Commission. These figures have in turn been analysed by our Consulting Engineer and as stated under the second analysis given, he has revised the estimates submitted by the engineers of the Commission to a basis which makes additional allowance for contingencies, reserve for renewals and so forth, sufficient to cover maximum requirements. It is pointed out in this





connection that the estimates submitted by the engineers of the Commission did not include any item whatsoever for contingencies and that the rate in respect of reserve for renewals is somewhat less than that used herein.

In our opinion, basis (b) should be considered for use by the Commission in setting up operating costs in respect of this Development.

In our report on the Niagara System, we have dealt at some length with the favoured condition which the Greater Niagara System enjoys on account of the extended sinking fund period on the Queenston-Chippawa Development, and a similar condition in connection with the bonded indebtedness of the power companies which are owned and operated by the Commission. According to the figures arrived at by our Accountants, we have shown that this advantage in terms of dollars and cents will amount to about \$800,000 annually.

Owing to the complications involved, it is impossible to compute with accuracy the extent to which the annual cost per horse-power to municipalities on the Greater Niagara System would be increased if sinking funds for the power plants at Niagara were established on a thirty-year basis contemplated by the Power Commission Act. Suffice it to say, however, that the increase would be considerable.

Taking into account the completed condition of the Queenston-Chippawa Power Development, capable of delivering 550,000 electrical horse-power, and assuming that the Electrical Development Company and The Ontario Power Company are operating in conjunction with the Queenston plant, giving a total output capacity of about 800,000 horse-power, the extra yearly charges which would be added, if the operation of these





plants placed on the same basis as the plants in other systems, would amount to the sum just quoted, namely, \$800,000, less a comparatively small amount applicable to the transmission lines and other equipment taken over in connection with the "Clean-up" deal.

It follows, therefore, that, if the horse-power billed to the Greater Niagara System remained constant at 800,000 horse-power, the rates applicable would be increased by \$1.00 per horse-power. Having regard to the fact, however, that the horse-power billed will be some amount less than this, the extra cost per horse-power will be proportionately increased.

Referring to another part of this report wherein is quoted statements from a letter of September 13th, 1915, by Sir Adam Beck submitted to the Premier, the following passage should be observed:

"It was found that on the basis of an ultimate 300,000 h.p. capacity for the permanent works, and with 100,000 h.p. equipment installed, the development could be made for \$10,500,000 with an annual charge of approximately \$944,500.00 per annum, including operation, interest, sinking fund, maintenance and all other operating charges, or an equivalent of \$9.44 per h.p. per annum for 100,000 h.p. without depreciation and sinking fund, the annual charges for 100,000 h.p. would be \$7.00 and for 75,000 h.p.,- \$9.20.

"Estimates were also prepared to cover capacities up to 200,000 and 300,000 h.p. which indicate that 200,000 h.p. can be developed at a price not exceeding \$7.00 and 300,000 h.p. at a price not exceeding \$6.00 per annum including interest, sinking fund and depreciation charges."

Now it will be noted that at the time this statement was made a maximum development of 300,000 horse-power was contemplated and it was predicted that the price per horse-power would not exceed \$6.00 including





all charges. At that time the Commission was figuring interest at 5%. Since the above statement was made interest charges have increased, and are now being figured at about 6%. On the other hand the \$6.00 rate is figured on a thirty-year sinking fund basis equivalent to an annual charge of about 1.8% on the capital invested. The sinking fund now figured by the Commission is on a forty-year basis which reduces the annual charge from 1.8% to 1%, correspondingly reducing the annual cost of power. Depreciation charges, commonly known as reserve for renewals, were figured upon a much higher basis in 1915 than at the present time. In 1915, they were probably more than twice as great as are now being used by the Commission. It would appear that any advantage gained by decreasing yearly sinking fund amounts and depreciation charges is approximately offset by the increase in interest rate. It may be considered, therefore, that if the cost of power in 1915 was \$6.00 per horse-power per annum, it would be practically the same figure at the present time if construction costs had been accurately estimated in the first instance. Construction costs of all kinds increased enormously during the period from 1915 to 1921 when the Queenston-Chippawa Power Development was being made, and, generally speaking, the purchasing power of a dollar towards the end of that period was about half of that of 1915. It is therefore unfair to compare an estimated cost of \$6.00 per horse-power made in 1915 with present costs unless the general inflation of prices be taken into consideration together with the specific local conditions found during the construction of the Development.

The fact remains that the cost of power from the Chippawa plant will actually be between \$15.00 per horse-power per annum at present and about \$12.50 or \$13.00 per horse-power per annum in the future when the completed plant is operating at full load.





On the basis of actual conditions, it might be stated that the effect of the increased construction costs after 1915 is that the actual cost of power from the Queenston-Chippewa Power Development is between two and two and one-half times the estimated figure made public by Sir Adam Beck in his letter quoted above.

There is another matter that should be kept in mind when making these comparisons; namely, that the estimate of capital cost made in 1915, on which the estimate of the cost per horse-power was based, does not represent a plant of the capacity as built, nor does it in many respects represent the unit costs as used in Estimate No. 2 of 1917, which was the estimate under which the construction was proceeded with. On the other hand, as far as we have been able to learn, the statement made by Sir Adam Beck in his letter of September 13th, 1915, regarding the annual cost per horse-power of energy from the Development contains the only figures which were given publicity at the time the Development was under consideration.

We have shown in our report on the Niagara System that on January 1st, 1917, a vote was submitted to the ratepayers of over 70 municipalities in the Niagara System, asking for the endorsement of a plan whereby the Commission would be authorized to acquire operating companies or construct developments necessary for the supply of electrical energy to the Niagara System. The figures quoted in the letter of September 13th, 1915, above referred to, were undoubtedly in the minds of the people who voted on this question, and, as we have stated, little or no publicity was given to any other figures subsequent to that time.





Effect of Capital Costs on  
Annual Cost per Horse-Power

In a former report we state that there are very few, if any, undertakings in which interest charges on the capital investment play so important a part in annual cost as in the generation of electrical energy. In connection with the same subject, we show that on the basis of the estimates of the Commission interest on the capital invested represents approximately 70% of all the charges entering into the annual cost of generating power in the combined plants at Niagara.

Sinking fund is the next important item and represents approximately 13% of the cost, using a forty-year sinking fund period. Therefore, the remaining 17% is distributed amongst operation, maintenance, depreciation and so forth. From this it is apparent that the capital cost is the direct regulator of the annual cost per horse-power. Putting this fact in its simplest terms it may be stated that the capital cost per horse-power directly regulates the annual cost per horse-power. The extent to which this statement may be applied varies for different conditions, but in the case of the Queenston-Chippawa Power Development it applies more forcibly than in any other development operated by the Commission. In another section of this report we have set forth all estimates prepared by the engineers of the Commission or by consultants employed by it from June 23rd, 1915, to January, 1923. For purposes of convenience we repeat certain of the information contained in that table, as follows:



Office of Capital Losses on

Annual Report for 1911

It is hereby ordered that the following be published:

Statement of the Commission on the Capital Losses of the

State of Massachusetts for the year 1911, as required by

the Commission on the Capital Losses of the State of the

Commission on the Capital Losses of the State of the

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Date of Estimate	Nominal Installation Horse-Power	Canal Capacity Approximately		Total Amount of Estimate in Dollars	Approximate Capital Cost per Horse-Power
		cu.ft. per sec.	Horse-Power		
(a) June 23/15	100,000	6,550	Varying	10,410,233	104*
(b) Jan. 5/16	200,000	8,550	Varying	13,149,803	65
(c) Nov. 27/17	300,000	10,000	300,000	24,316,816	81
(d) Feb. 5/18	300,000	10,000	300,000	24,000,000	80
(e) Jan. 8/19	300,000	15,000	500,000	25,102,915	84*
(f) Late in 1919	300,000	15,000	500,000	27,025,635	90*
(g) Jan. 29/23	300,000	15,000	500,000	64,370,180	214*
(h) Jan. 29/23	500,000	15,000	500,000	74,677,367	149
(i) Jan. 29/23	550,000	18,000	550,000	80,729,014	147

The figures in the column headed "Approximate Capital Cost per Horse-Power" are arrived at by dividing the total amount of estimate in dollars by the nominal installation horse-power. In cases where the installation is only part of the capacity of the development as a whole, the figures in the column headed "Approximate Capital Cost per Horse-Power" are marked with a star, thus \*, and are not comparable amongst themselves nor with those not so designated with a star. It will thus be seen that there are in the table given above five cases on a corresponding basis.

As a matter of fact, the last estimate bearing date January 29th, 1923, lettered (i), above, was again revised on February 21st, 1923, the estimated capital cost being given to our Consulting Engineer as \$82,483,914. Dividing this by the nominal installation horse-power, 550,000, we get an approximate capital cost per horse-power of \$150.00. Accepting this as a final figure, and comparing it with the estimates in three of the cases in which they are comparable, we get the following:



Year	Population	Area	Population	Area	Population	Area
1990	1,000,000	100,000	1,000,000	100,000	1,000,000	100,000
1991	1,000,000	100,000	1,000,000	100,000	1,000,000	100,000
1992	1,000,000	100,000	1,000,000	100,000	1,000,000	100,000
1993	1,000,000	100,000	1,000,000	100,000	1,000,000	100,000
1994	1,000,000	100,000	1,000,000	100,000	1,000,000	100,000
1995	1,000,000	100,000	1,000,000	100,000	1,000,000	100,000
1996	1,000,000	100,000	1,000,000	100,000	1,000,000	100,000
1997	1,000,000	100,000	1,000,000	100,000	1,000,000	100,000
1998	1,000,000	100,000	1,000,000	100,000	1,000,000	100,000
1999	1,000,000	100,000	1,000,000	100,000	1,000,000	100,000
2000	1,000,000	100,000	1,000,000	100,000	1,000,000	100,000

above five cases on a corresponding basis.

as designated with a star. It will then be seen that there are in the table

also, that "A" and are not numbered - a simple oversight and will soon be

being located - approximately 1000 feet per second - and would not be

only part of the quantity of the movement in a circle. The figures in the

by the present investigation. In cases where the insulation in

investigation are subject to the following the following of factors in relation

The figures in the column headed "Approximate Capital Cost per

It is a matter of fact, that the first estimate was made in 1900, and the second in 1901, and the third in 1902, and the fourth in 1903, and the fifth in 1904, and the sixth in 1905, and the seventh in 1906, and the eighth in 1907, and the ninth in 1908, and the tenth in 1909, and the eleventh in 1910, and the twelfth in 1911, and the thirteenth in 1912, and the fourteenth in 1913, and the fifteenth in 1914, and the sixteenth in 1915, and the seventeenth in 1916, and the eighteenth in 1917, and the nineteenth in 1918, and the twentieth in 1919, and the twenty-first in 1920, and the twenty-second in 1921, and the twenty-third in 1922, and the twenty-fourth in 1923, and the twenty-fifth in 1924, and the twenty-sixth in 1925, and the twenty-seventh in 1926, and the twenty-eighth in 1927, and the twenty-ninth in 1928, and the thirtieth in 1929, and the thirty-first in 1930, and the thirty-second in 1931, and the thirty-third in 1932, and the thirty-fourth in 1933, and the thirty-fifth in 1934, and the thirty-sixth in 1935, and the thirty-seventh in 1936, and the thirty-eighth in 1937, and the thirty-ninth in 1938, and the fortieth in 1939, and the forty-first in 1940, and the forty-second in 1941, and the forty-third in 1942, and the forty-fourth in 1943, and the forty-fifth in 1944, and the forty-sixth in 1945, and the forty-seventh in 1946, and the forty-eighth in 1947, and the forty-ninth in 1948, and the fiftieth in 1949, and the fifty-first in 1950, and the fifty-second in 1951, and the fifty-third in 1952, and the fifty-fourth in 1953, and the fifty-fifth in 1954, and the fifty-sixth in 1955, and the fifty-seventh in 1956, and the fifty-eighth in 1957, and the fifty-ninth in 1958, and the sixtieth in 1959, and the sixty-first in 1960, and the sixty-second in 1961, and the sixty-third in 1962, and the sixty-fourth in 1963, and the sixty-fifth in 1964, and the sixty-sixth in 1965, and the sixty-seventh in 1966, and the sixty-eighth in 1967, and the sixty-ninth in 1968, and the seventieth in 1969, and the seventy-first in 1970, and the seventy-second in 1971, and the seventy-third in 1972, and the seventy-fourth in 1973, and the seventy-fifth in 1974, and the seventy-sixth in 1975, and the seventy-seventh in 1976, and the seventy-eighth in 1977, and the seventy-ninth in 1978, and the eightieth in 1979, and the eighty-first in 1980, and the eighty-second in 1981, and the eighty-third in 1982, and the eighty-fourth in 1983, and the eighty-fifth in 1984, and the eighty-sixth in 1985, and the eighty-seventh in 1986, and the eighty-eighth in 1987, and the eighty-ninth in 1988, and the ninetieth in 1989, and the ninety-first in 1990, and the ninety-second in 1991, and the ninety-third in 1992, and the ninety-fourth in 1993, and the ninety-fifth in 1994, and the ninety-sixth in 1995, and the ninety-seventh in 1996, and the ninety-eighth in 1997, and the ninety-ninth in 1998, and the hundredth in 1999, and the hundred-first in 2000, and the hundred-second in 2001, and the hundred-third in 2002, and the hundred-fourth in 2003, and the hundred-fifth in 2004, and the hundred-sixth in 2005, and the hundred-seventh in 2006, and the hundred-eighth in 2007, and the hundred-ninth in 2008, and the hundred-tenth in 2009, and the hundred-eleventh in 2010, and the hundred-twelfth in 2011, and the hundred-thirteenth in 2012, and the hundred-fourteenth in 2013, and the hundred-fifteenth in 2014, and the hundred-sixteenth in 2015, and the hundred-seventeenth in 2016, and the hundred-eighteenth in 2017, and the hundred-nineteenth in 2018, and the hundred-twentieth in 2019, and the hundred-twenty-first in 2020, and the hundred-twenty-second in 2021, and the hundred-twenty-third in 2022, and the hundred-twenty-fourth in 2023, and the hundred-twenty-fifth in 2024, and the hundred-twenty-sixth in 2025, and the hundred-twenty-seventh in 2026, and the hundred-twenty-eighth in 2027, and the hundred-twenty-ninth in 2028, and the hundred-thirtieth in 2029, and the hundred-thirty-first in 2030, and the hundred-thirty-second in 2031, and the hundred-thirty-third in 2032, and the hundred-thirty-fourth in 2033, and the hundred-thirty-fifth in 2034, and the hundred-thirty-sixth in 2035, and the hundred-thirty-seventh in 2036, and the hundred-thirty-eighth in 2037, and the hundred-thirty-ninth in 2038, and the hundred-fortieth in 2039, and the hundred-forty-first in 2040, and the hundred-forty-second in 2041, and the hundred-forty-third in 2042, and the hundred-forty-fourth in 2043, and the hundred-forty-fifth in 2044, and the hundred-forty-sixth in 2045, and the hundred-forty-seventh in 2046, and the hundred-forty-eighth in 2047, and the hundred-forty-ninth in 2048, and the hundred-fiftieth in 2049, and the hundred-fifty-first in 2050, and the hundred-fifty-second in 2051, and the hundred-fifty-third in 2052, and the hundred-fifty-fourth in 2053, and the hundred-fifty-fifth in 2054, and the hundred-fifty-sixth in 2055, and the hundred-fifty-seventh in 2056, and the hundred-fifty-eighth in 2057, and the hundred-fifty-ninth in 2058, and the hundred-sixtieth in 2059, and the hundred-sixty-first in 2060, and the hundred-sixty-second in 2061, and the hundred-sixty-third in 2062, and the hundred-sixty-fourth in 2063, and the hundred-sixty-fifth in 2064, and the hundred-sixty-sixth in 2065, and the hundred-sixty-seventh in 2066, and the hundred-sixty-eighth in 2067, and the hundred-sixty-ninth in 2068, and the hundred-seventieth in 2069, and the hundred-seventy-first in 2070, and the hundred-seventy-second in 2071, and the hundred-seventy-third in 2072, and the hundred-seventy-fourth in 2073, and the hundred-seventy-fifth in 2074, and the hundred-seventy-sixth in 2075, and the hundred-seventy-seventh in 2076, and the hundred-seventy-eighth in 2077, and the hundred-seventy-ninth in 2078, and the hundred-eightieth in 2079, and the hundred-eighty-first in 2080, and the hundred-eighty-second in 2081, and the hundred-eighty-third in 2082, and the hundred-eighty-fourth in 2083, and the hundred-eighty-fifth in 2084, and the hundred-eighty-sixth in 2085, and the hundred-eighty-seventh in 2086, and the hundred-eighty-eighth in 2087, and the hundred-eighty-ninth in 2088, and the hundred-ninetieth in 2089, and the hundred-ninety-first in 2090, and the hundred-ninety-second in 2091, and the hundred-ninety-third in 2092, and the hundred-ninety-fourth in 2093, and the hundred-ninety-fifth in 2094, and the hundred-ninety-sixth in 2095, and the hundred-ninety-seventh in 2096, and the hundred-ninety-eighth in 2097, and the hundred-ninety-ninth in 2098, and the hundred-hundredth in 2099, and the hundred-hundred-first in 2100, and the hundred-hundred-second in 2101, and the hundred-hundred-third in 2102, and the hundred-hundred-fourth in 2103, and the hundred-hundred-fifth in 2104, and the hundred-hundred-sixth in 2105, and the hundred-hundred-seventh in 2106, and the hundred-hundred-eighth in 2107, and the hundred-hundred-ninth in 2108, and the hundred-hundred-tenth in 2109, and the hundred-hundred-eleventh in 2110, and the hundred-hundred-twelfth in 2111, and the hundred-hundred-thirteenth in 2112, and the hundred-hundred-fourteenth in 2113, and the hundred-hundred-fifteenth in 2114, and the hundred-hundred-sixteenth in 2115, and the hundred-hundred-seventeenth in 2116, and the hundred-hundred-eighteenth in 2117, and the hundred-hundred-nineteenth in 2118, and the hundred-hundred-twentieth in 2119, and the hundred-hundred-twenty-first in 2120, and the hundred-hundred-twenty-second in 2121, and the hundred-hundred-twenty-third in 2122, and the hundred-hundred-twenty-fourth in 2123, and the hundred-hundred-twenty-fifth in 2124, and the hundred-hundred-twenty-sixth in 2125, and the hundred-hundred-twenty-seventh in 2126, and the hundred-hundred-twenty-eighth in 2127, and the hundred-hundred-twenty-ninth in 2128, and the hundred-hundred-thirtieth in 2129, and the hundred-hundred-thirty-first in 2130, and the hundred-hundred-thirty-second in 2131, and the hundred-hundred-thirty-third in 2132, and the hundred-hundred-thirty-fourth in 2133, and the hundred-hundred-thirty-fifth in 2134, and the hundred-hundred-thirty-sixth in 2135, and the hundred-hundred-thirty-seventh in 2136, and the hundred-hundred-thirty-eighth in 2137, and the hundred-hundred-thirty-ninth in 2138, and the hundred-hundred-fortieth in 2139, and the hundred-hundred-forty-first in 2140, and the hundred-hundred-forty-second in 2141, and the hundred-hundred-forty-third in 2142, and the hundred-hundred-forty-fourth in 2143, and the hundred-hundred-forty-fifth in 2144, and the hundred-hundred-forty-sixth in 2145, and the hundred-hundred-forty-seventh in 2146, and the hundred-hundred-forty-eighth in 2147, and the hundred-hundred-forty-ninth in 2148, and the hundred-hundred-fiftieth in 2149, and the hundred-hundred-fifty-first in 2150, and the hundred-hundred-fifty-second in 2151, and the hundred-hundred-fifty-third in 2152, and the hundred-hundred-fifty-fourth in 2153, and the hundred-hundred-fifty-fifth in 2154, and the hundred-hundred-fifty-sixth in 2155, and the hundred-hundred-fifty-seventh in 2156, and the hundred-hundred-fifty-eighth in 2157, and the hundred-hundred-fifty-ninth in 2158, and the hundred-hundred-sixtieth in 2159, and the hundred-hundred-sixty-first in 2160, and the hundred-hundred-sixty-second in 2161, and the hundred-hundred-sixty-third in 2162, and the hundred-hundred-sixty-fourth in 2163, and the hundred-hundred-sixty-fifth in 2164, and the hundred-hundred-sixty-sixth in 2165, and the hundred-hundred-sixty-seventh in 2166, and the hundred-hundred-sixty-eighth in 2167, and the hundred-hundred-sixty-ninth in 2168, and the hundred-hundred-seventieth in 2169, and the hundred-hundred-seventy-first in 2170, and the hundred-hundred-seventy-second in 2171, and the hundred-hundred-seventy-third in 2172, and the hundred-hundred-seventy-fourth in 2173, and the hundred-hundred-seventy-fifth in 2174, and the hundred-hundred-seventy-sixth in 2175, and the hundred-hundred-seventy-seventh in 2176, and the hundred-hundred-seventy-eighth in 2177, and the hundred-hundred-seventy-ninth in 2178, and the hundred-hundred-eightieth in 2179, and the hundred-hundred-eighty-first in 2180, and the hundred-hundred-eighty-second in 2181, and the hundred-hundred-eighty-third in 2182, and the hundred-hundred-eighty-fourth in 2183, and the hundred-hundred-eighty-fifth in 2184, and the hundred-hundred-eighty-sixth in 2185, and the hundred-hundred-eighty-seventh in 2186, and the hundred-hundred-eighty-eighth in 2187, and the hundred-hundred-eighty-ninth in 2188, and the hundred-hundred-ninetieth in 2189, and the hundred-hundred-ninety-first in 2190, and the hundred-hundred-ninety-second in 2191, and the hundred-hundred-ninety-third in 2192, and the hundred-hundred-ninety-fourth in 2193, and the hundred-hundred-ninety-fifth in 2194, and the hundred-hundred-ninety-sixth in 2195, and the hundred-hundred-ninety-seventh in 2196, and the hundred-hundred-ninety-eighth in 2197, and the hundred-hundred-ninety-ninth in 2198, and the hundred-hundred-hundredth in 2199, and the hundred-hundred-hundred-first in 2200, and the hundred-hundred

1. Increase of final cost over  
estimate of January 5th, 1915 ..... \$85.00 per h.p. or 131%.
2. Increase of final cost over  
estimate of November 27th, 1917 ..... \$69.00 per h.p. or 85%.
3. Increase of final cost over  
estimate of February 5th, 1918 ..... \$70.00 per h.p. or 88%.

We have previously shown that the annual cost per horse-power to the Niagara System will be somewhat more than twice the amount originally estimated upon in 1915. Comparing this ratio of increase with the ratio of increase in capital cost per horse-power developed, it will be noted that while the ratio is not greatly different, the ratio of increase in the capital cost per horse-power is less than the ratio of increase in the annual cost per horse-power. It is quite natural that this is so, for the development as now being constructed has nearly twice the capacity of that estimated upon in 1917, but the works necessary to obtain this capacity are far from being twice the extent of those contemplated in the 1917 estimate. It may be stated generally that the capital cost per horse-power developed decreases within certain limits as the capacity increases.

In another report we have stated that the annual cost of power bears a fairly definite percentage ratio to the capital cost per horse-power developed, varying probably between 8% and 14%. In this report we have shown that the annual cost of power from the Queenston-Chippawa Power Development when fully loaded will vary from \$12.50 to about \$14.00 per horse-power at the bus-bars. It follows, therefore, that, in this Development, the annual cost of power is between 8% and 9% of the capital cost per horse-power developed.

With this fact in mind it is interesting to observe the effect



1. The Commission has found that the annual cost of power for the United States is approximately \$1.4 billion in 1954, or about 1.4 percent of the gross national product. This cost is expected to increase to about \$2.0 billion in 1960, or about 2.0 percent of the gross national product.

2. The Commission has also found that the annual cost of power for the United States is expected to increase to about \$2.0 billion in 1960, or about 2.0 percent of the gross national product. This cost is expected to increase to about \$2.5 billion in 1965, or about 2.5 percent of the gross national product.

3. The Commission has also found that the annual cost of power for the United States is expected to increase to about \$2.5 billion in 1965, or about 2.5 percent of the gross national product. This cost is expected to increase to about \$3.0 billion in 1970, or about 3.0 percent of the gross national product.

that an increase in the capital cost would have on the annual cost of power. Assuming that a plant capable of developing 550,000 horse-power at a capital cost of \$82,000,000 should have cost \$11,000,000, less, or \$71,000,000 under ordinary circumstances, the excess cost of \$11,000,000 represents \$20.00 capital cost per horse-power for a 550,000 horse-power plant. Assuming that the annual cost per horse-power represents about 9% of the capital cost of developing, the price of power would be affected to the extent of only \$1.80 per horse-power per annum. It will, therefore, be noted that a development of this character might have an increase of many millions of dollars in capital cost without affecting to a very marked extent the annual cost per horse-power.

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There is still another view of this matter which should be taken into consideration, namely, that our analysis has been based upon the sale of power at the bus-bars of the generating station. This power is in reality distributed to the municipalities, the local authorities of which sell it on a retail basis to their customers. As the sale of power increases and as its consumption is spread over a variety of uses, the value of the diversity factor increases, and the municipalities may, and usually do, receive revenue from the sale of much greater amounts of power than they actually purchase from the Commission. Therefore, any excesses or increases in cost of power billed them by the Commission may be entirely absorbed or offset when diversity is taken into consideration. Nevertheless, if there is an excess or an unwarranted increase in the cost of power, the economic loss still exists and the excess





expenditure can never be recovered.

Summary

We have shown that the increase in the annual cost of power delivered from the Queenston-Chippawa Power Development varies almost in the same ratio as the increase of actual over estimated capital cost. We will set forth in a later part of this report our opinion as to what the actual cost should have been, but speaking generally it may be stated now that the increases in the cost of power to the Niagara System over the cost predicted in 1915 are directly caused by the increased capital cost of the work, which increase is largely due to the unusual way in which the work was carried out, and to the conditions prevailing at that time. It may also be stated that, even when work of this nature costs a great deal more than it should, the effect on the annual cost of power is not so great as might be expected.





















